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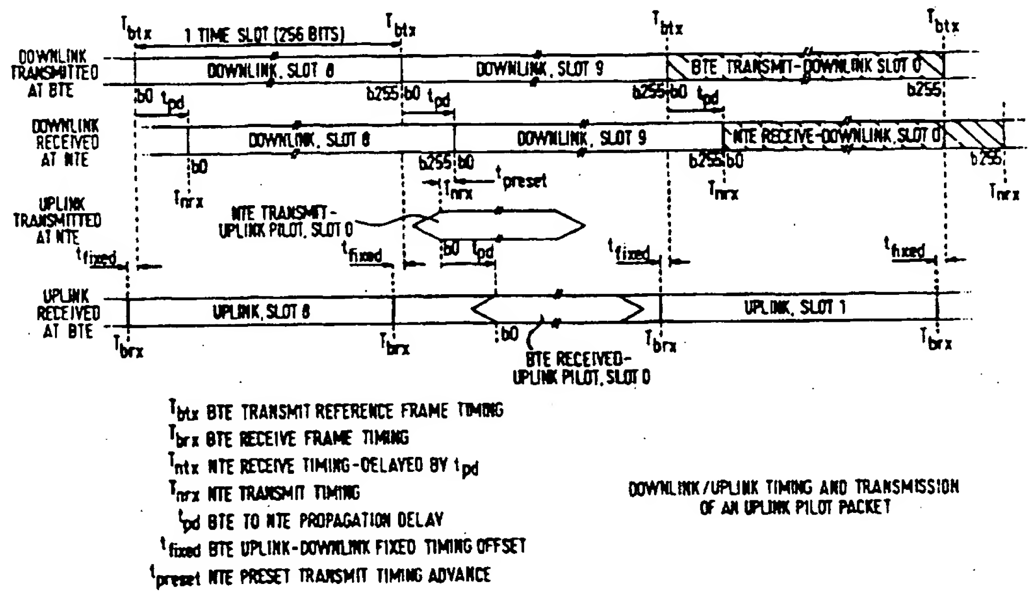

DOWNLINK/UPLINK TIMING AND TRANSMISSION OF AN UPLINK PILOT PACKET

(57) Abstract

In time domain multiplex/time domain multiple access communications between a base station and subscriber unit, the base station sends a timing reference signal. A subscriber unit responds with a data packet (a) sufficiently short to ensure correct reception by the base irrespective of transmission time. The base determines the transmission time taken and instructs the subscriber unit to advance its timings so that longer data packets (b) can be sent so as to be received when expected. The timing adjustment includes both a fixed present component dependent on approximate separation of base station and subscriber unit, and a second component from measurement of the transmission time taken.

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Transmission Timing Control in Digital Radio Telephony

This invention relates to controlling the timing of transmission of data packets in predetermined time slots of fixed length time frames.

Time division multiplex/time division multiple access (TDM/TDMA) communication requires that signals from various subscriber units communicating with a base station must reach the base station at appropriate times, otherwise, portions of two or more data packets from different subscriber units might reach the base station at the same instant, and then the base station would not be able to receive all packets correctly. In conventional TDM/TDMA systems, such as GSM ("Global System for Mobile communications") systems, a base station sends reference timing signals to the subscriber units, having informed each subscriber unit how much in advance of the reference signal it should transmit in order that transmissions from the subscriber units are received with the correct timing at the base station. In consequence, each data packet is correctly aligned in its TDMA time slot at the base station. Without such adaptive time alignment, packets would have to be separated by sufficiently large guard periods to allow for the possible maximum time delay between subscriber units and the base station, resulting in inefficient spectrum usage.

The present invention in its various aspects is defined in the claims to which reference should now be made.

The present invention in one aspect preferably relates to a method of controlling the timing of transmissions from subscriber units for reception by a base station in predetermined time slots, in which the base station transmits a timing reference signal to a subscriber unit, the subscriber unit transmits a relatively short pilot packet which is received by the base station, the base station determines a value dependent upon the propagation delay between the base station and subscriber unit from the time of reception of the pilot packet, and the base station informs the subscriber unit to advance the timing of subsequent transmissions from the subscriber unit in response thereto.

The timing adjustment for a subscriber unit includes a first fixed component which is predetermined according to the approximate separation of subscriber unit and base station, and a second component determined by measuring the time for arrival of the pilot packet from the subscriber unit. The second component can be variable, and once the second component is determined, a message is sent to the subscriber unit setting the timing adjustment to be used for subsequent information packets.

Adaptive time alignment according to the present invention involves transmission of pilot packets from a subscriber unit to the base station. Pilot packets are of shorter duration than normal packets. The shorter duration of pilot packets ensures that pilot packets are received from different subscriber units at the base station such that they do not overlap in time. Pilot packets can contain system control data and/or short information messages, whereas normal packets, which are longer, can contain both system control data and other information, such as user data.

Another aspect of the invention preferably relates to a method of TDMA call establishment in which an aloha request for call establishment is transmitted in a pilot packet, pilot packets being sent repeatedly over a period of time for reception by the base station, a pilot packet being relatively shorter than a normal packet. Thus, if one pilot packet is not received correctly, or does not enable a timing adjustment to be determined, the aloha request can still be received correctly, or the timing adjustment can still be determined, using a subsequent pilot packet. A subsequent pilot packet can be set at a different frequency to ensure reliable reception under various environmental conditions.

Another aspect of the present invention is preferably to transmit initialising packets from the base station to a subscriber unit, an initialising packet including a sequence of timing signals used in adjustment of timing of signals from the subscriber unit to the base station.

The timing adjustment of packets between a base station and subscriber units in a system can include a fixed component so as to offset in time up-link and down-link transmissions.

In another aspect, the invention preferably relates to a method of adjustment of timing of up-link and down-link packets, in a TDMA system, including a reference signal being sent from the base station, a pilot packet being sent from a subscriber unit in response to said reference signal, a timing adjustment being determined at the base station from the timing of receipt of said pilot packet, and a signal representative of said timing

adjustment being transmitted to the subscriber unit to adjust its timing. Once adjustment has been made, normal length packets can be transmitted.

The present invention also relates to apparatus for carrying out these methods.

A preferred embodiment of the invention will now be described by way of example with reference to the drawings in which:

Figure 1 is a schematic diagram illustrating the system including a base station (BTE - Base Terminating Equipment) and subscriber unit (NTE - Network Equipment);

Figure 2 is a diagram illustrating frame structure and timing for a duplex link;

Figure 3 is a diagram showing down-link/up-link timing and the transmission of an up-link pilot packet, where up-link is from a subscriber unit (NTE - Network Terminal Equipment) to a base station (BTE - Base Terminal Equipment);

Figure 4 is a diagram showing timing adjustment for a normal packet which is transmitted up-link;

Figure 5(a) is a representation of an up-link pilot packet;

Figure 5(b) is a representation of an up-link normal packet for comparison with the up-link pilot packet shown in Figure 3(a);

Figure 6(a) is a representation of a down-link pilot packet;

Figure 6(b) is a representation of a down-link normal packet, for comparison with Figure 6(a).

The Basic System

As shown in Figure 1, the preferred system is part of a telephone system in which the local wired loop from exchange to subscriber has been replaced by a full duplex radio link between a fixed base station and fixed subscriber unit. The preferred system includes the duplex radio link, and transmitters and receivers for implementing the necessary protocol. There are similarities between the preferred system and digital cellular mobile telephone systems such as GSM which are known in the art. This system uses a protocol based on a layered model, in particular the following layers: PHY (Physical), MAC (Medium Access Control), DLC (Data Link Control), NWK (Network).

One difference compared with GSM is that, in the preferred system, subscriber units are at fixed locations and there is no need for hand-off arrangements or other features relating to mobility. This means, for example, in the preferred system directional antennae and mains electricity can be used.

Each base station in the preferred system provides six duplex radio links at twelve frequencies chosen from the overall frequency allocation, so as to minimize interference between base stations nearby. The frame structure and timing for a duplex link is

illustrated in Figure 2. Each duplex radio link comprises an up-link from a subscriber unit to a base station and, at a fixed frequency offset, a down-link from the base station to the subscriber unit. The down-links are TDM, and the up-links are TDMA. Modulation for all links is $\pi/4$ - DQPSK, and the basic frame structure for all links is ten slots per frame of 2560 bits. The bit rate is 512kbps. Down-links are continuously transmitted and incorporate a broadcast channel for essential system information. When there is no user information to be transmitted the down-link transmissions continue to use the basic frame and slot structure and contain a suitable fill pattern.

For both up-link and down-link transmissions, there are two types of slot: normal slots which are used after call set-up, and pilot slots used during call set-up.

As shown in Figure 6b, each down-link normal slot comprises 24 bits of synchronisation information, followed by 24 bits designated S-field which includes an 8 bit header, followed by 160 bits designated D-field. This followed by 24 bits Forward Error Correction, and an 8-bit tail, followed by 12 bits of the broadcast channel. The broadcast channel consists of segments in each of the slots of a frame which together form the down-link common signalling channel which is transmitted by the base station, and contains control messages containing link information such as slot lists, multi-frame and super-frame information, connectionless messages and other information basic to the operation of the system.

During call set-up, each down-link pilot slot contains, as shown in Figure 6a, frequency correction data and a training sequence for receiver initialization, with only a short S-

field and no D- field information.

Up-link slots basically contain two different types of data packet, as shown in Figure 5. The first type of packet, called a pilot packet, is used before a connection is set up, for example, for an Aloha call request and to allow adaptive time alignment (see Figure 5a). The other type of data packet, called a normal packet, is used when a call has been established and is a larger data packet, due to the use of adaptive time alignment (see Figure 5b).

Each up-link normal packet contains a data packet of 244 bits which is proceeded and followed by a ramp of 4 bits duration. The ramps and the remaining bits left of the 256 bit slot provide a guard gap against interference from neighbouring slots due to timing errors. Each subscriber unit adjusts the timing of its slot transmissions to compensate for the time it takes signals to reach the base station. Each up-link normal data packet comprises 24 bits of synchronisation data followed by an S-field and D-field of the same number of bits as in each down-link normal slot.

Each up-link pilot slot contains a pilot data packet which is 192 bits long preceded and followed by 4 bit ramps defining an extended guard gap of 60 bits. This larger guard gap is necessary because there is no timing information available and without it propagation delays would cause neighbouring slots to interfere. The pilot packet comprises 64 bits of sync followed by 104 bits of S-field which starts with an 8 bit header and finishes with a 16 bit Cyclic Redundancy Check, 2 reserved bits, 14 forward error correction FEC bits, and 8 tail bits. There is no D-field.

The S-fields in the above mentioned data packets can be used for two types of signalling. The first type is MAC signalling (MS) and is used for signalling between the MAC layer of the base station and the MAC layer of a subscriber unit whereby timing is of importance. The second type is called associated signalling, which can be slow or fast and is used for signalling between the base station and subscriber units in the DLC or NWK layers.

The D-field is the largest data field, and in the case of normal telephony contains digitised speech samples, but can also provide non-speech data samples.

Provision is made in the preferred system for subscriber unit authentication using a challenge response protocol. General encryption is provided by combining the speech or data with a non-predictable sequence of cipher bits produced by a key stream generator which is synchronised to the transmitted super-frame number.

In addition, the transmitted signal is scrambled to remove dc components.

Adaptive time alignment

Adaptive time alignment allows the guard period between normal up-link packets to be reduced by compensating for the time delay in propagation.

For a given subscriber unit, the round trip propagation delay (base to subscriber to base) is determined at the base by comparing the timing of the received packets to the down-link timing. The base programmes the subscriber unit to transmit at times advanced by

the measured round trip propagation time, so as to ensure packets are received by the base precisely within the respective time slots allocated for their reception.

Without adaptive time alignment, the guard period allowed when normal up-link packets are used, would be insufficient. Accordingly, until the normal transmission timing of the subscriber unit is set, a normal packet cannot be sent as there is a danger it will collide with the contents of the following time slot. In this situation, it is an up-link pilot packet which is transmitted. The pilot packet being shorter allows an extended guard period which enables it to be correctly received without requiring any adjustment of the subscriber unit transmission timing.

The maximum range between the base station and a subscriber unit that can be supported using an up-link pilot packet with no timing advance, is approximately 10 km. Beyond this range, the round trip propagation time exceeds the extended guard period provided by using the shorter pilot packets. However, for greater ranges, a further preset timing advance can be provided which means subscriber units at greater distances can be used. The preset advance is applied to up-link pilot packet transmissions such that a transmitted pilot packet is received within the correct time slot by the base. The base compares the timing of the received packet to the down-link timing, and programmes the subscriber unit with a corresponding advance, known as an adaptive advance. The total advance applied to an up-link normal packet transmission is then the sum of the preset advance and the adaptive advance. The total advance is equal to the round trip propagation time.

The precise timing relationships between up-link and down-link packets is illustrated in Figure 3, and the timing of an up-link normal packet with adaptive time alignment is shown in Figure 4.

The timing between up-link packets and down-link packets is also adjusted by a timing offset t_{fixed} shown in Figures 3 and 4 for both up-link pilot packets and up-link normal packets.

The following parameters are defined for adaptive time alignment:

Resolution of adaptive advance, tadv = 1 bit
Minimum adaptive advance, tadv = 0 bits
Maximum adaptive advance, tadv = 36 bits (= 10 km maximum range Subscriber to Base)

Resolution of preset advance, t_{preset} = 1 bit
Minimum preset advance, t_{preset} = 0 bits

Maximum total timing advance at the Subscriber, $t_{adv}+t_{preset}$ = 104 bits

The preset timing advance is programmed as part of the subscriber unit installation process and is set to 0 if the subscriber unit is within the maximum range of 10 km supported by the variable component alone.

However, outside of this range subscribers may be grouped in zones according to their range from the base station with which they are registered and corresponding larger preset advances t_{preset} allocated to them as follows:-

Zone	Min Range (km)	Max Range (km)	t_{preset}(bits)
A	0	10	0
B	5	15	17
C	10	20	34
D	15	25	51
E	20	30	68

Min Range corresponds to the actual minimum range supported by a total timing advance equal to t_{preset} + minimum t_{adv}; Max range corresponds to the actual maximum range supported by a total timing advance equal to t_{preset} + maximum t_{adv}.

CLAIMS

1. A method of controlling the timing of transmissions of data packets from at least one first transmitting and receiving unit for reception by a second transmitting and receiving unit in predetermined time slots within fixed length time frames, in which the second unit transmits a timing reference signal to a first unit, the first unit transmits in response a relatively short first packet having guard periods long enough to ensure reception by the second unit, the second unit determines a value dependent upon the propagation delay from the time of reception of the first packet, and the second unit transmits an adjustment signal dependent upon the value to the first unit to adjust the timing of subsequent transmissions of relatively long packets from the subscriber unit in response thereto.

2. A method of controlling the timing of transmissions according to claim 1, in which transmissions are by radio.

3. A method of controlling the timing of transmissions according to claim 1 or claim 2, in which each first unit comprises a subscriber unit at a fixed location and the second unit is a base station.

4. A method of controlling the timing of transmissions according to any preceding claim, in which the guard periods of the first packet are long enough to ensure reception by a base station irrespective of the propagation delay between the base station and subscriber unit.

5. A method of controlling the timing of transmissions according to any preceding claim, in which the timing adjustment signal for a subscriber unit includes a first fixed component which is preset according to the approximate separation of subscriber unit and base station, and a second component determined by measuring the time of reception of the first packet from the subscriber unit.

6. A method of controlling the timing of transmissions according to any preceding claim, in which once the second component is determined, the adjustment signal is sent to the subscriber unit to set the timing adjustment to be used for subsequent information packets.

7. A method of controlling the timing of transmissions according to any preceding claim, in which the first packet contains system control data and/or short information messages.

8. A method of controlling the timing of transmissions according to any preceding claim, in which normal packets contain both system control data and other information, such as user data.

9. Timing control means for controlling the timing of transmission of data packets from a first transmitting and receiving unit for reception by a second transmitting and receiving unit in predetermined time slots within fixed length time frames, in which the second unit comprises timing reference signal transmission means, and the first unit comprises response means operative to transmit in response to receipt

of a timing reference signal a relatively short first packet having guard periods large enough to ensure reception by the second unit, the second unit further comprising determination means operative to determine a value dependent upon the propagation delay from the time of reception of the first packet, and the second unit further comprising controlling means operative to transmit an adjustment signal dependent upon the value to the first unit, the first unit further comprising adjustment means operative to adjust the timing of subsequent transmissions of relatively long packets in response thereto.

10. Timing control means according to claim 9, in which the controlling means transmits an adjustment signal including a first fixed component and a second component, the first fixed component being preset according to the approximate separation of the first unit and the second unit and the second component being determined by measuring the time for transmission of the first packet from the subscriber unit.

11. Timing control means according to claim 9 or claim 10, in which the second unit comprises a base station and the first unit comprises a subscriber unit at a fixed location.

12. A method of adjustment of timing of up-link and down-link packets sent in time slots within fixed length time frames, including a reference signal being sent from the base station, a relatively short first packet being sent from a subscriber unit in response to said reference signal, a timing adjustment being determined by the base station from the timing of receipt of said first packet, and an adjustment signal

dependent upon said timing adjustment being transmitted to the subscriber unit to adjust its timing of subsequent transmissions of relatively long packets.

13. A method of call establishment in which transmissions are sent in predetermined time slots within fixed length time frames, and in which an aloha request for call establishment is transmitted by a subscriber unit in a pilot packet, a pilot packet being relatively shorter than a normal packet, pilot packets being sent repeatedly over a period of time for reception by a base station so as to enable correct reception of the aloha request and/or correct determination of a timing adjustment should the first pilot packet not be received.

14. A method according to claim 13, in which a subsequent pilot packet is sent at a different frequency.

15. A method of controlling the timing of transmission of data packets from subscriber units to a base station in predetermined time slots within fixed length time frames, including transmitting an initialising packet from the base station to a subscriber unit, an initialising packet including timing data, and adjusting the timing of signals from the subscriber unit to the base station in response to the timing data.

16. A method of controlling the timing of transmission of data packets according to claim 15, in which the timing data from the base station to the subscriber unit includes a fixed component dependent upon the separation of base station and subscriber unit.

17. A method of controlling the timing of transmission of data packets according to claim 15 or claim 16, in which the timing data includes a variable component determined by measuring the time for transmission between the base station and the subscriber unit.

18. Timing control means for controlling the timing of transmissions of TDMA data packets from subscriber units to a base station in predetermined time slots, the base station including means for transmitting an initialising packet to the subscriber unit, an initialising packet including timing data, and the subscriber unit including signal transmission means and adjustment means to adjust the timing of signals transmitted by the signal transmission means in response to the timing data.

19. Timing control means according to claim 18, in which adjustment is by applying a timing offset having a fixed component dependent upon the separation of base station and subscriber unit.

20. Timing control means according to claim 18 or claim 19, in which adjustment is by applying a variable component determined by measuring the time for transmission between the base station and the subscriber unit.

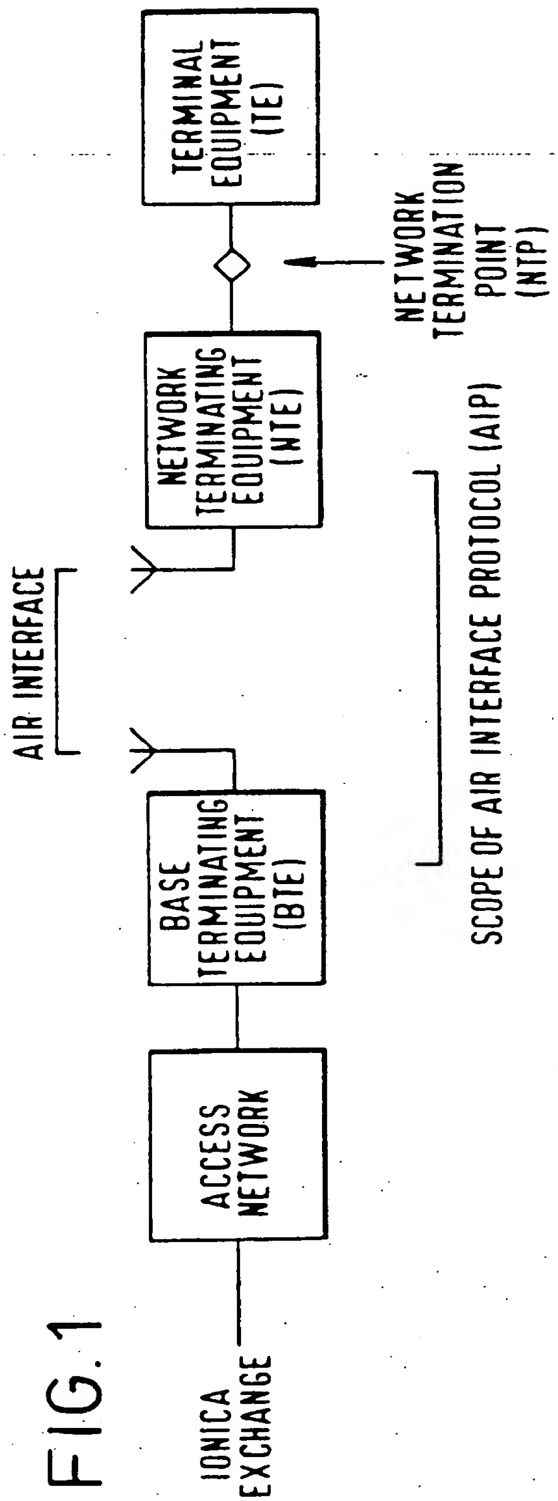

IONICA EXCHANGE
ACCESS NETWORK
BASE TERMINATING EQUIPMENT (BTE)
AIR INTERFACE
NETWORK TERMINATING EQUIPMENT (NTE)
NETWORK TERMINATION POINT (NTP)
TERMINAL EQUIPMENT (TE)
SCOPE OF AIR INTERFACE PROTOCOL (AIP)

FIG.1

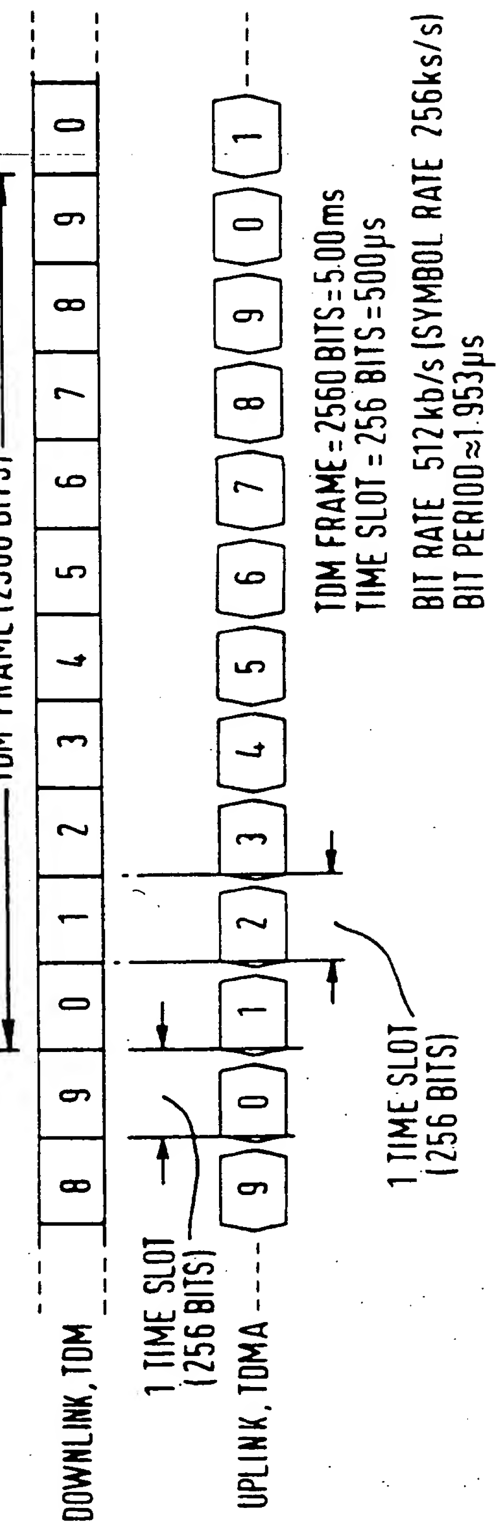

DOWNLINK, TDM
UPLINK, TDMA
TDM FRAME (2560 BITS)
1 TIME SLOT (256 BITS)
1 TIME SLOT (256 BITS)
TDM FRAME = 2560 BITS = 5.00ms
TIME SLOT = 256 BITS = 500μs
BIT RATE 512 kb/s (SYMBOL RATE 256ks/s)
BIT PERIOD≈1.953μs

FIG. 2

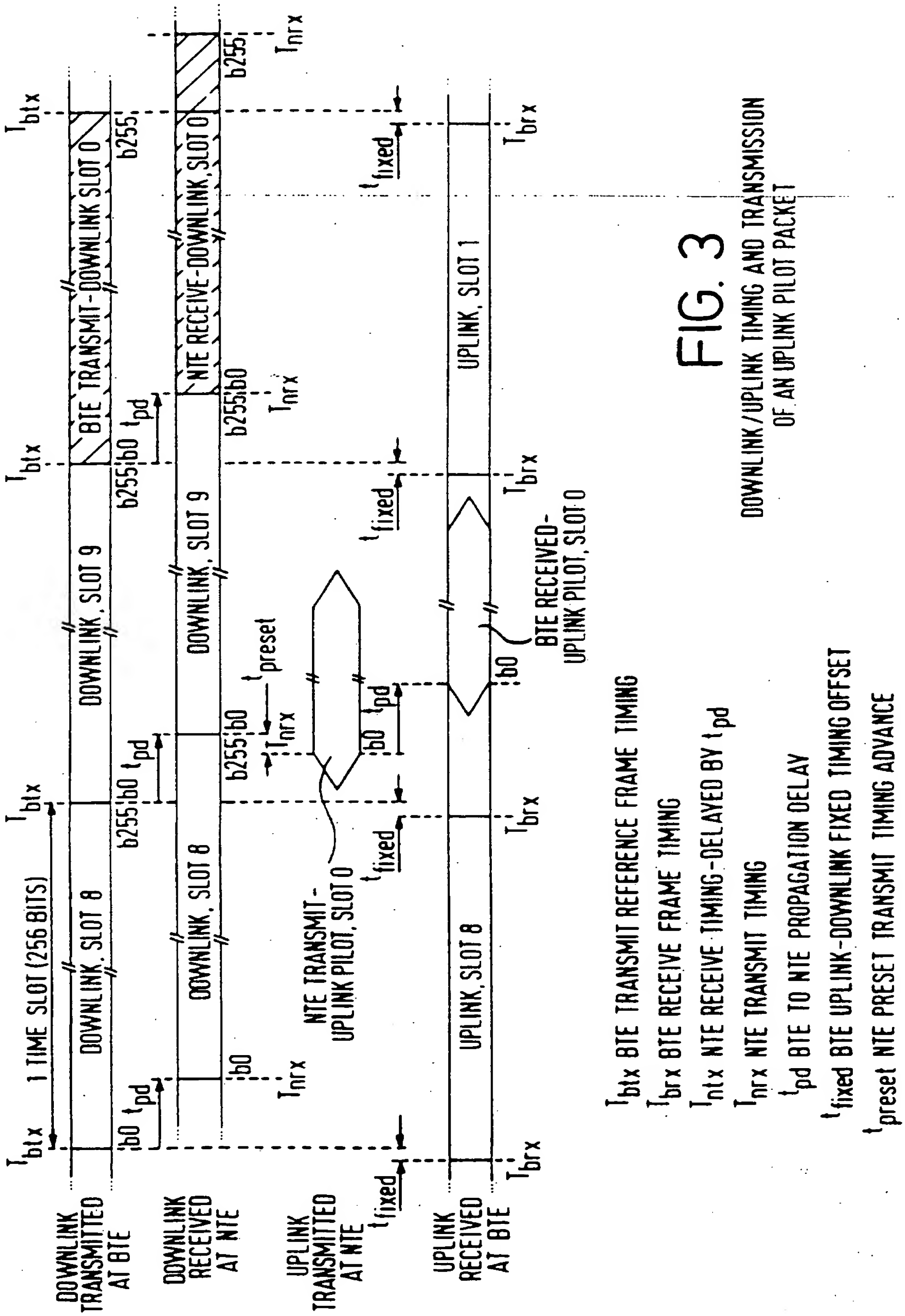


FIG. 3

DOWNLINK/UPLINK TIMING AND TRANSMISSION OF AN UPLINK PILOT PACKET

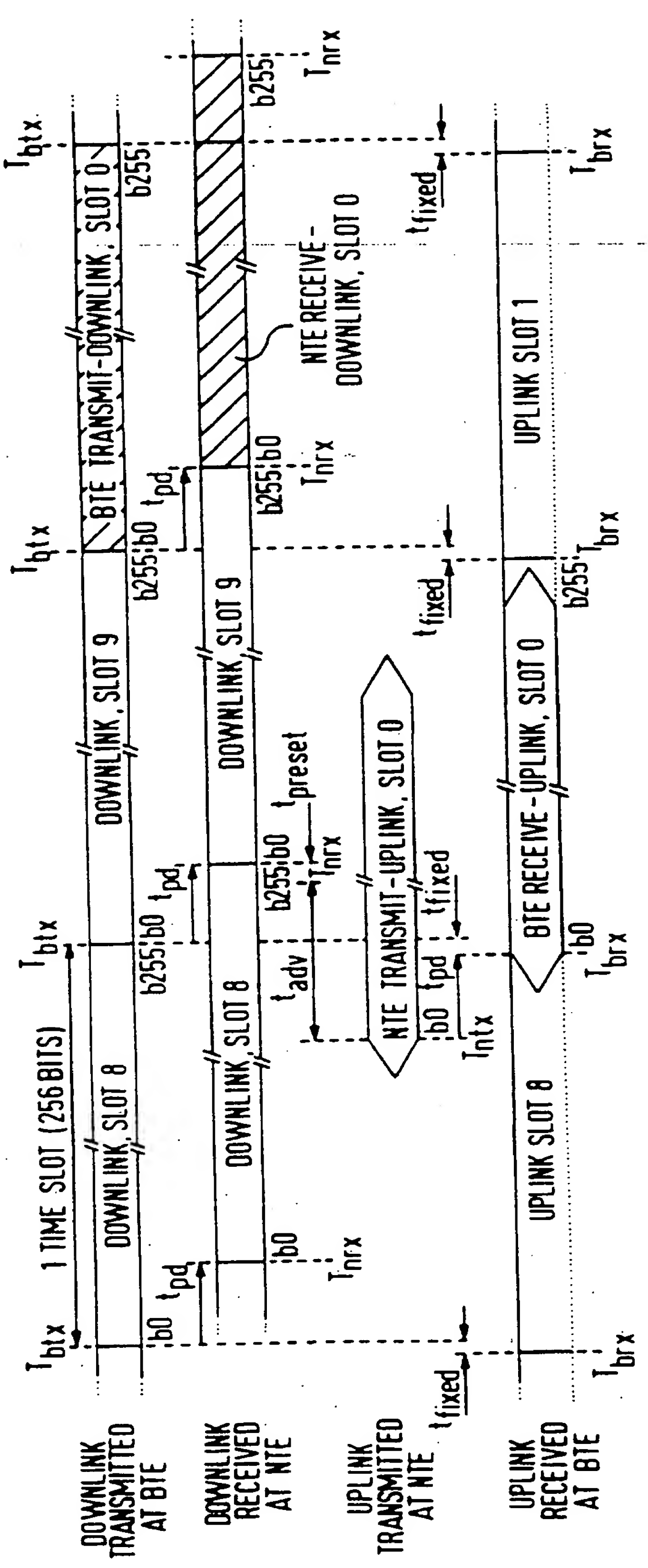


FIG. 4

TRANSMISSION OF AN UPLINK NORMAL PHYSICAL PACKET USING NTE ADAPTIVE TIME ALIGNMENT

T_{btx} BTE TRANSMIT REFERENCE FRAME TIMING
T_{brx} BTE RECEIVE FRAME TIMING
T_{ntx} NTE RECEIVE TIMING-DELAYED BY t_{pd}
T_{nrx} NTE TRANSMIT TIMING
t_{pd} BTE TO NTE PROPAGATION DELAY
t_{fixed} BTE UPLINK-DOWNLINK FIXED TIMING OFFSET
t_{preset} NTE PRESET TRANSMIT TIMING ADVANCE
t_{adv} NTE ADAPTIVE TRANSMIT TIMING ADVANCE

FIG. 5(a)

UPLINK PILOT PHYSICAL PACKET
SLOT N

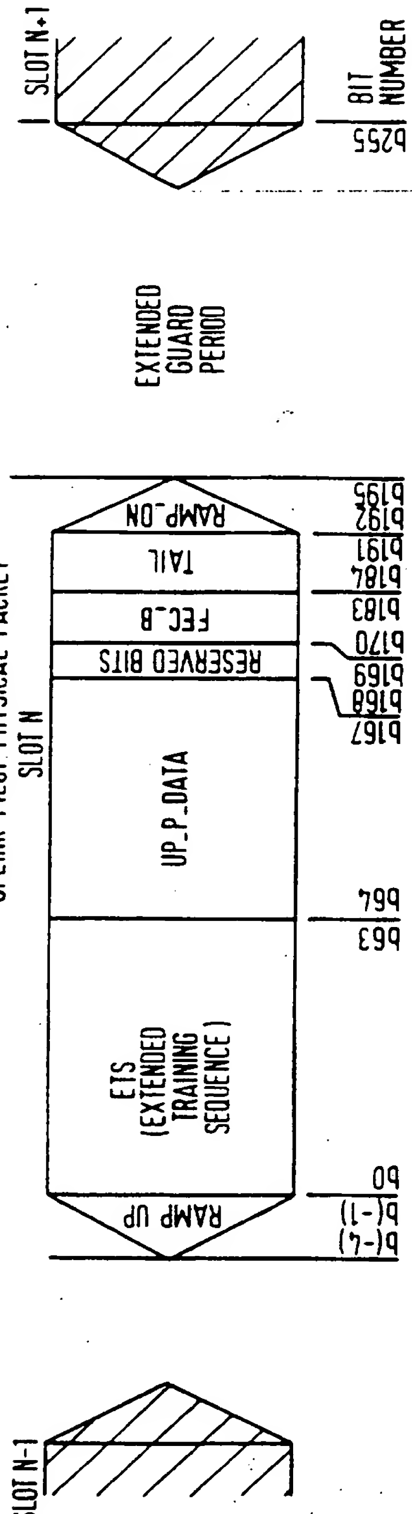
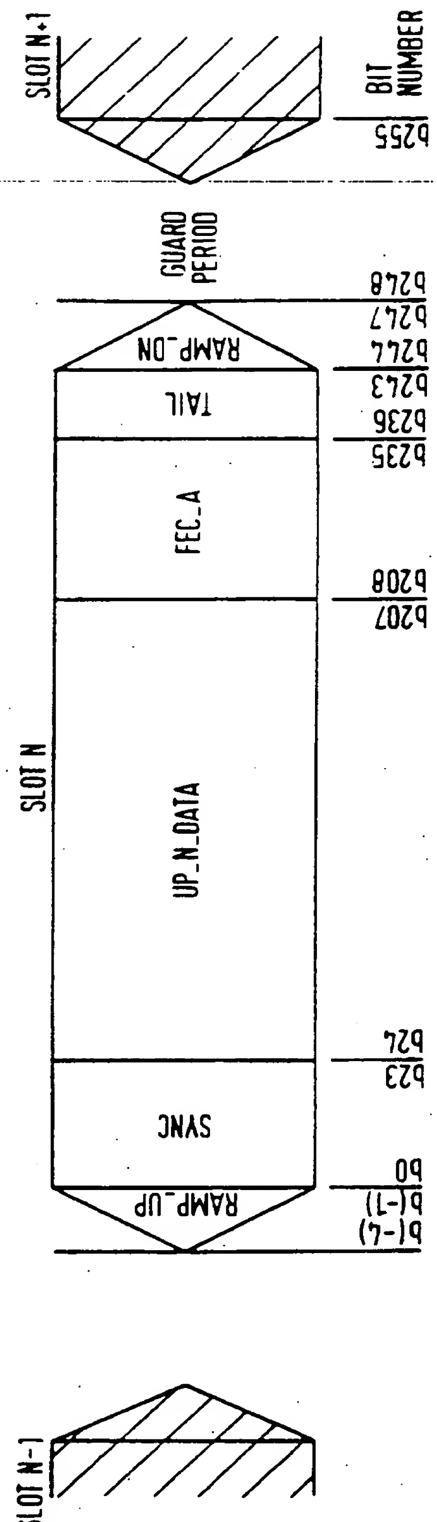


FIG. 5(b)

UPLINK NORMAL PHYSICAL PACKET
SLOT N



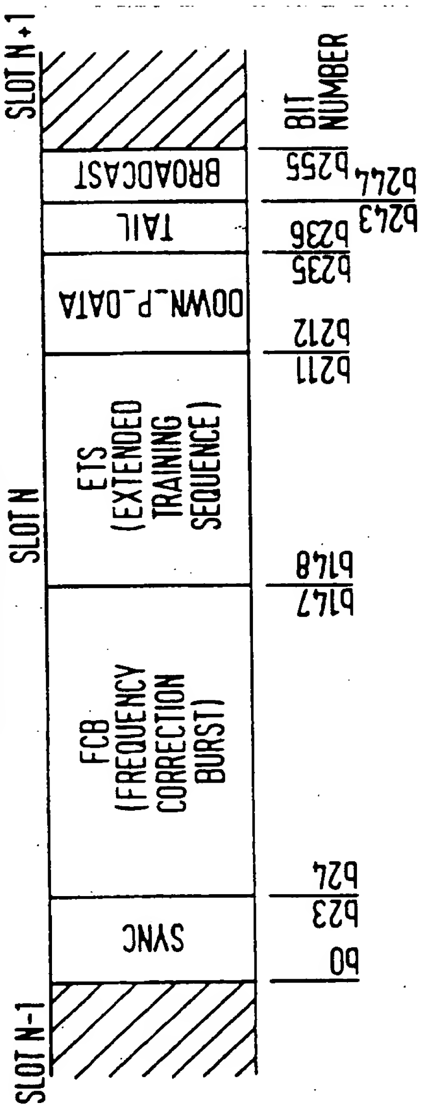


FIG. 6(a)
DOWNLINK PILOT PACKET

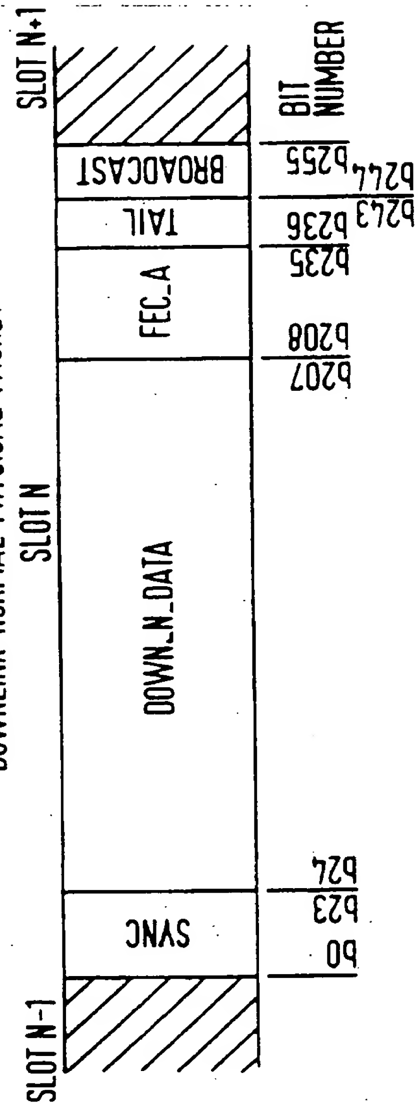


FIG. 6(b)
DOWNLINK NORMAL PHYSICAL PACKET

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B7/26 H04J3/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

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IPC 6 H04Q H04B H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 007 no. 115 (E-176) ,19 May 1983 & JP,A,58 036034 (NIPPON DENSHIN DENWA KOSHA) 2 March 1983, see abstract	1,2,4,9, 12,15,18
A	PHILIPS TELECOMMUNICATION AND DATA SYSTEMS REVIEW, vol. 47, no. 2, June 1989 HILVERSUM NL, pages 1-19, XP 000054481 M. DE COUESNONGLE ET AL. 'IRT 2000: System for telephone and data at remote sites' see page 7, line 6 - page 8, line 4	

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☐ Patent family members are listed in annex.

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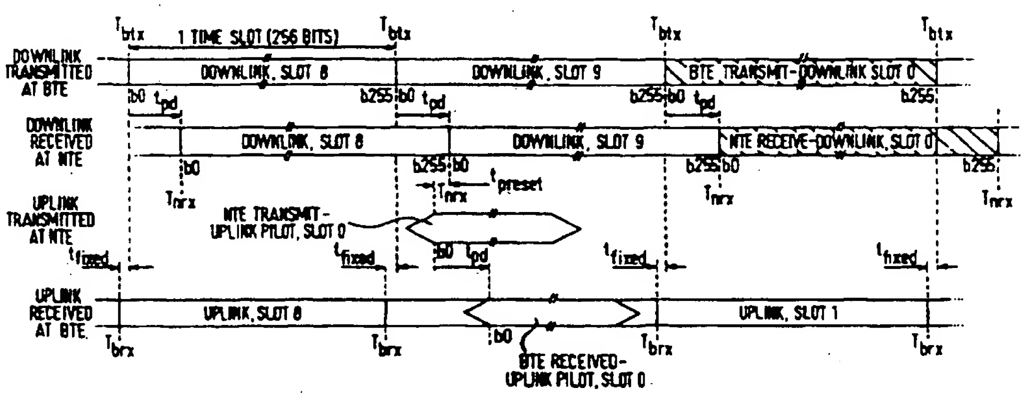

T_{btx} BTE TRANSMIT REFERENCE FRAME TIMING
T_{brx} BTE RECEIVE FRAME TIMING
T_{ntx} NTE RECEIVE TIMING-DELAYED BY t_{pd}
T_{nrx} NTE TRANSMIT TIMING
t_{pd} BTE TO NTE PROPAGATION DELAY
t_{fixed} BTE UPLINK-DOWNLINK FIXED TIMING OFFSET
t_{preset} NTE PRESET TRANSMIT TIMING ADVANCE

DOWNLINK/UPLINK TIMING AND TRANSMISSION OF AN UPLINK PILOT PACKET

(57) Abstract

In time domain multiplex/time domain multiple access communications between a base station and subscriber unit, the base station sends a timing reference signal. A subscriber unit responds with a data packet (a) sufficiently short to ensure correct reception by the base irrespective of transmission time. The base determines the transmission time taken and instructs the subscriber unit to advance its timings so that longer data packets (b) can be sent so as to be received when expected. The timing adjustment includes both a fixed present component dependent on approximate separation of base station and subscriber unit, and a second component from measurement of the transmission time taken.

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INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q H04B H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 007 no. 115 (E-176) ,19 May 1983 & JP,A,58 036034 (NIPPON DENSHIN DENWA KOSHA) 2 March 1983, see abstract ---	1,2,4,9, 12,15,18
A	PHILIPS TELECOMMUNICATION AND DATA SYSTEMS REVIEW, vol. 47, no. 2, June 1989 HILVERSUM NL, pages 1-19, XP 000054481 M. DE COUESNONGLE ET AL. 'IRT 2000: System for telephone and data at remote sites' see page 7, line 6 - page 8, line 4 -----	

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